The degradation of land snail shells during the annual dry period in a Mediterranean climate

La degradación de las conchas de moluscos terrestres durante el período seco anual en un clima mediterráneo

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ABSTRACT

The shell degradation of eight common Mediterranean land mollusc species was experimentally investigated during the annual dry period (June to September). The results suggest that insolation was an important factor in degradation but that the background coloration of the support on which the shells were attached was not a significant factor. Larger species degraded less rapidly than smaller ones. *Cantareus aspersus* (Müller, 1774) took the longest time to degrade, possibly because the periostracum protects the underlying shell. A shell Condition Index is used that allows the scoring of shells and their inclusion or not in species matrices.

RESUMEN

La degradación de las conchas de ocho especies de moluscos terrestres comunes en el Mediterráneo fue investigada experimentalmente durante el período anual de sequía (Junio a Septiembre). Los resultados sugieren que la insolación constituye un factor importante en la degradación, pero que el color de fondo del emplazamiento donde los moluscos estaban fijados no era un factor significativo. Las especies de mayor tamaño se degradaron más lentamente que las pequeñas. *Cantareus aspersus* (Müller, 1774) fue la más lenta en degradarse, posiblemente debido al periostraco que protege la concha. Un Indice del estado de la concha se utiliza para calificar las conchas y su inclusión, o no, en las matrices de especies.

KEY WORDS: Land snail shells, degradation, Mediterranean climate
PALABRAS CLAVE: Conchas de moluscos terrestres, degradación, clima Mediterráneo

INTRODUCTION

'How long has that shell been empty?' This is a question most collectors ask when picking up an empty snail shell. For a collector the answer may not be critical: as long as the shell is in good condition it may be added to the collection. For the ecologist, using standardized data collection techniques (MENEZ, 2001; 2002), the answer is much more pertinent. If the shell is very recent it

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indicates an individual that, until death, utilized resources, interacted with biotic and abiotic components, and formed part of the molluscan biomass. These facts are also true of an older shell but the difference is in the time elapsed from death to recording of the shell by the investigator. In the former case, contemporary biotic and abiotic data may apply to the specimen; in the latter it may not because conditions may have changed significantly from the time of death of the specimen to the recording of data. Dead shells are often included in species matrices used in diversity studies (Nilsson, Bengtsson and As, 1988; Winter, 1995; Emberton, 1997; Emberton, Pearce, Kasigwa, Tattersfield and Habibu, 1997), but often with no indication of shell condition. A knowledge of the elapsed period since death is crucial in the inclusion or not of the specimen in the species matrix for an area under ecological study.

Species matrices composed of abundances are affected by the inclusion of dead shells in a quantitative manner for the species recorded. Species matrices composed only of presence/absence data may reflect lower species numbers for an area if only species found as live specimens are included. This is particularly true if substratum samples are analyzed for micro-species that often are only found dead. Examples of these species are *Truncatellina cylindrica*, *Cecilioides acicula* and *Acicula* spp., the last of which are mostly known only from dead specimens.

Some of the factors that contribute to shell degradation are known (e.g. pH, humidity) and have been reported (Evans 1972; Claassen, 1998) but there is much scope for experimental, and consequently objective, study of shell degradation. In this paper I examine one major factor in degradation that is particularly relevant in Mediterranean regions: insolation. My fieldwork during many years suggests that shells on open ground degrade rapidly during the dry period of the year (unpublished data). In the Mediterranean this period is generally from June to September (Blondel and Aronson, 1999) and coincides with decreased, or cessation of activity of most land molluscs.

Data collection for diversity and distributional studies are carried out during the wet period (October to May) when mollusc activity is pronounced. Should empty shells found during this period be included in the species matrices? To help answer this I exposed the shells of eight species to the sun during the dry period and measured shell degradation.

METHODS

Forty live adult specimens of each of eight common land mollusc species were collected from sites in south Iberia: *Ferussacia follicula* (Gmelin, 1790) and *Otala lactea* (Müller, 1774) from Westside (Gibraltar); *Xerotricha apicina* (Lamarck, 1822), *Cochlicella acuta* (Müller, 1774) and *Caracollina lenticula* (Michaud, 1831) from Catalan Bay (Gibraltar); *Rumina decollata* (Linnaeus, 1758) from Marbella (Spain); *Theba pisana* (Müller, 1774) from Casares (Spain) and *Cantareus aspersus* (Müller, 1774) from both Marbella and Casares (Spain). The experimental layout consisted of two wooden boards each divided equally in two. One half was painted white and the other black, to test effects of background coloration. Ten shells of each species with the animals removed were attached, aperture downwards, to the two halves of each of the two boards using Blu-Tack®. The adhesive was attached at the midline of the shell leaving a space of 2mm between the shell and the board. Both of the boards were placed on a roof terrace, in Gibraltar, receiving sunlight from sunrise until sunset. One was exposed to the sun, the other was kept in darkness as a control.

The condition of each shell was scored using a simple index (SCI, see Table I) every three days. Scoring began on 1 June 2000 and ended on 2 October 2000 (124 days), representing the dry period (see Introduction). Temperature (°C), total rainfall (mm) and total suns-

Table I. Shell Condition Index (SCI) showing descriptions of shell condition for each score.
Tabla I. Indice del estado de la concha (SCI) con descripción de estado para cada valor.

Score	Description of shell condition
1	Perfect shell. No loss of gloss. Periostracum intact. No shell damage
2	<10% loss of gloss. <10% lifting of periostracum. <1% area of shell damaged
3	10-50% loss of gloss. 10-50% lifting of periostracum. 1-5% area of shell damaged
4	50-75% loss of gloss. 50-75% lifting of periostracum. >5% area of shell damaged
5	75-95% loss of gloss. 75-95% lifting, or loss, of periostracum. >5% area of shell damaged
6	Total loss of gloss. Total loss of periostracum. >5% area of shell damaged
7	As score 6 but shell brittle

hine (hours) data were provided courtesy of the Gibraltar Meteorological Office. Values for these variables during the experimental period were within the ranges for the 30-year data set from 1968 to 1997 (Table II).

Each of the species were assigned to a geometric type and biometric data measured (Table III). *X. apicina* and *C. lenticula* were designated discoidal, *F. follicula* and *R. decollata* cylindrical, *C. aspersus*, *O. lactea* and *T. pisana* spherical, and *C. acuta* conical. Shell height and width, and apertural height and width were measured with calipers to 0.01mm. Shell volume and surface area were calculated using geometric formulae (VAN STIGT, 1974).

RESULTS

The time, in days, that 50% and 100% of shells attained each of the SCI scores is shown in Table IV. All shells were scored SCI 2 at the beginning of the experiment because perfect shells were not obtained after killing and removing the animals. There was no significant difference between the white and black sides of the board for any of the species (paired samples t-tests: *F.*

Table II. Monthly mean temperature, total rain and total sunshine for the experimental period, and ranges for the same months from a 30-year data set (1968-1997). Data courtesy of the Gibraltar Meteorological Office.
Tabla II. Medias mensuales de temperatura, lluvia total y horas de sol para el período de experimentación, y rangos para los mismos meses para un periodo de 30 años (1968-1997). Datos por cortesía del Gibraltar Meteorological Office.

Month/year	Mean temperature (°C)	Total rain (mm)	Total sunshine (hours)
June 2000	22.8	0	308
July 2000	23.4	0	334
August 2000	23.8	0	304
September 2000	22.7	9	225
Ranges 1968-1997			
June	17.4-25.0	0-147	264-358
July	19.7-27.7	0-8	276-368
August	20.4-28.3	0-135	258-361
September	19.2-26.0	0-119	194-306

Table III. Biometric data (mm) for all species (n= 40 for each species) showing mean, standard deviation and range for each.
Tabla III. Datos biométricos (mm) para todas especies (n= 40 para cada especie) con media, desviación estándar y rango para cada una.

Species	Height	Width	Volume	Surface area	Apertural area
F. follicula	8.53±0.52	3.48-0.19	81.54±13.47	112.38±12.20	7.94±1.10
	7.4-9.6	3.2-4.0	63.32-120.69	93.86-145.83	5.78-10.35
R. decollata	23.56±3.05	9.71±0.73	1783.76±533.03	873.64±171.36	44.48±10.60
	18.8-33.9	8.3-12.6	1055.49-4228.69	616.93-1591.92	26.13-91.02
X. apicina	3.99±0.60	6.14±1.16	127.74±65.35	134.48±50.12	9.19±2.43
	2.4-5.2	4.2-8.9	26.49-304.96	23.47-261.53	5.25-15.21
C. acuta	12.69±0.92	5.07±0.36	86.22±15.77	118.04±15.49	10.57±2.12
	10.8-14.7	4.3-5.7	54.76-116.46	85.05-147.36	7.14-17.94
C. aspersus	28.51±2.31	30.35±2.50	9221.84±2349.76	2113.28±348.30	362.99±65.11
	25.2-34.9	26.4-38.1	5966.52-17325.61	1591.07-3238.43	255.78-540.54
O. lactea	21.18±1.26	28.99±3.05	6058.84±1039.02	1601.75±190.91	173.03±23.05
	18.3-24.5	16.9-32.5	3004.23-7989.66	1007.00-1932.98	126.69-232.44
T. pisana	12.25±0.93	16.82±1.42	1743.18±586.05	677.28±92.25	70.27±11.01
	10.1-14.7	12.8-20.3	1124.46-4663.89	523.00-940.63	55.38-104.00
C. lenticula	3.30±0.24	7.20±0.39	135.07±21.17	156.36±16.35	5.58±0.81
	2.7-3.7	6.3-8.0	101.86-186.06	115.83-193.60	4.56-8.06

follicula: p= 0.140; *R. decollata*: p= 0.353; *X. apicina*: p= 0.203; *C. acuta*: p= 0.363; *C.aspersus*: p= 0.391; *O.lactea*: p= 0.391;*T. pisana*: p= 0.203; *C. lenticula*: p= 0.611). There was no change from SCI 2 in any of the shells of any species in the controls during the experimental period.

The maximal scores attained for each species, and the days elapsed for this to occur (for both halves of the board) are shown in Table V. This table also shows the percentage of shells with the maximal SCI score.

Table VI shows the mean surface area and mean apertural area for each species and the mean number of days elapsed to attain each of the SCI scores. The species with smaller surface areas attained higher SCI scores in less time than those with larger surface areas (χ^2 test: p< 0.001). The species with smaller apertural areas attained higher SCI scores in less time than those with larger apertural areas (χ^2 test: p< 0.001).

The spherical species (*O. lactea* and *C. aspersus*) degraded the least during the experimental period (Table VI). This may be a consequence of larger surface area and apertural area, rather than geometric shape. Support for this hypothesis is provided by the degradation rates for the two cylindrical species, *F. follicula* and *R. decollata*, the former (with smaller surface area and apertural area) degrading faster than the latter. Apertural area may be related to shell size and surface area, with the larger species (which have larger surface areas) having larger apertural areas (Spearman's rho= 0.810, p= 0.015).

DISCUSSION

The larger species degraded less rapidly than the smaller species. Of all the species *C. aspersus* required the longest time interval for attainment of

Table IV. The time (in days) that 50 and 100% of shells attained each of the SCI scores. Colour refers to the white and black halves of the board onto which the shells were attached. The table shows results for the shells exposed to the sun; the shells on the control board, kept in darkness, did not change from SCI 2 during the experimental period (see text for details).
Tabla IV. El período (en días) en que el 50 y 100% de las conchas alcanzaron cada uno de los valores SCI. Colour se refiere a las mitades del tablero donde se fijaron las conchas. La tabla indica datos para las conchas expuestas al sol: las conchas control, mantenidas en oscuridad, no cambiaron el valor SCI 2 durante el período de experimentación (ver texto para detalles).

Species	Colour	Shell condition index (SCI)							
		3	3	4	4	5	5	6	6
	%	50	100	50	100	50	100	50	100
F. follicula	white	6	12	18	18	60	66	72	78
	black	3	9	18	18	51	66	72	78
R. decollata	white	12	18	51	60	84	84		
	black	12	18	51	60	84	84		
X. apicina	white	18	18	60	60	84	84		
	black	12	15	60	60	84	84		
C. acuta	white	12	12	18	18	72	72		
	black	12	12	18	18	72	72		
C. aspersus	white	51	51	84	90				
	black	51	51	84	90				
O. lactea	white	3	3	84	84				
	black	3	3	84	90				
T. pisana	white	6	6	48	48	84	90		
	black	6	6	48	48	72	84		
C. lenticula	white	15	15	42	42	60	69		
	black	18	18	33	42	60	66		

Table V. The maximal Shell Condition Index (SCI) scores attained for each species, and the days elapsed for this to occur for the white and black sides of the board. The table also shows the percentage of shells with the maximal SCI score.
Tabla V. Los valores máximos para el indice del estado de la concha (SCI) alcanzados para cada especie, y los dias que transcurrieron para estas, en las mitades blanca y negra del tablero. La tabla también indica el porcentaje de conchas con el SCI máximo.

Species	Maximal SCI		Days elapsed		% Shells with maximal SCI	
	White	Black	White	Black	White	Black
F. follicula	6	6	78	78	100	100
R. decollata	5	5	84	84	100	100
X. apicina	5	5	84	84	100	100
C. acuta	5	5	72	72	100	100
C. aspersus	5	5	111	111	10	30
O. lactea	5	5	114	111	30	40
T. pisana	5	5	90	84	100	100
C. lenticula	6	6	72	72	10	10

Table VI. The mean surface area (mm^2) and mean apertural area (mm^2) for each species and the mean number of days elapsed to attain each of the Shell Condition Index (SCI) scores.
Tabla VI. Media de area de superficie (mm^2) y media de area de abertura (mm^2) para cada especie y media de días transcurridos para alcanzar cada uno de los valores del indice del estado de la concha (SCI).

Species	Surface area	Apertural area	Mean number of days elapsed to SCI score			
			3	4	5	6
F. follicula	112.38	7.94	10.5	18	66	78
R. decollata	873.64	44.48	18	60	84	
X. apicina	134.48	9.19	51	90		
C. acuta	118.04	10.57	12	18	72	
C. aspersus	2113.28	362.99	51	90		
O. lactea	1601.75	173.03	3	87		
T. pisana	677.28	70.27	6	48	87	
C. lenticula	156.36	5.58	16.5	42	67.5	

SCI 3 (51 days). Colour preservation depends on the chemistry and stability of pigments and on shell mineralogy and exposure to sunlight fades pigments (CLAASSEN, 1998). The periostracum in *C. aspersus* possibly protects the underlying shell layer from pigment-fading and shell degradation. *O. lactea*, lacking this protective feature, degraded to SCI 3 in only 3 days, after which SCI 4 was attained in 84 days (the same as for *C. aspersus*).

Geometric shape is possibly not as important as surface area and apertural area in degradation rate. Because apertural area may be related to shell size and surface area, it is not possible to conclude that larger surface area and apertural area result, in themselves, in decreased degradation rates (rather than large shell size *per se*).

The surface temperatures of the boards were not measured but it may be assumed that the black side absorbed and retained more heat than the white. This was not a significant factor in degradation with no difference detected between the two sides of the board. This suggests that soil and rock coloration, on which specimens in the field might be collected, is not a significant factor in shell degradation. There was no degradation on the control board and the assumption is that insolation (possibly in conjunction with other, unmeasured, factors) contributes to shell degradation.

The data provide an indication of shells that may be included in a species abundance matrix for ecological study. All species attained a maximal SCI of at least 5 (*F. follicula* and *C. lenticula* attained SCI 6, see Table V). The inclusion of shells found in the field with an SCI score lower than 5 suggests that they will have been present in a dead state for a period less than the total duration of the annual dry period. The degradation rate of each species collected would need to be measured for a high level of confidence for this decision but this would be impractical. The data show that it may be acceptable to accept an SCI score of 4 for any species as a benchmark for inclusion in species matrices.

Further work would elucidate the role of other factors in shell degradation such as pH, moisture and the effects of soil cover. The latter would be particularly relevant for substratum samples. The effects of presence or absence of the dead animal inside the shell during degradation could also be studied. Additionally, species favouring locations under substratum (rocks, logs etc.) require special caution when assigning SCI values. These species dying *in situ*

and remaining in their locations would be protected from insolation effects.

The Index provides a guide for ecological fieldwork which is an improvement over current subjective criteria used for inclusion or exclusion of shells from species matrices. It is recognized, however, that there is much scope for its refinement which would increase its value in molluscan ecology.

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